

Claims

What is claimed is:

- 1 1. An apparatus, comprising:
2 a die;
3 a heat spreader mounted adjacent the die;
4 a thermal interface material interposed in a gap between the die and the heat
5 spreader; the thermal interface material comprising an array of carbon
6 nanotubes; and
7 at least one buffer layer disposed between the thermal interface material and
8 at least one of either the die or the heat spreader.

- 1 2. The apparatus of claim 1, wherein selected carbon nanotubes of the
2 array of carbon nanotubes are bonded to adjacent carbon nanotubes of the array
3 of carbon nanotubes.

- 1 3. The apparatus of claim 1, wherein a buffer layer is interposed
2 between the interface material and the die.

- 1 4. The apparatus of claim 1, wherein the buffer layer comprises a metal.

- 1 5. The apparatus of claim 1, wherein a portion of at least some carbon
2 nanotubes of the array of carbon nanotubes are coated with metal.

- 1 6. The apparatus of claim 3, wherein the buffer layer comprises a film
2 selected from the group consisting of Cr, Mo, Ti, SiC and TiC.

- 1 7. The apparatus of claim 1, wherein a buffer layer is interposed
2 between the thermal interface material and the heat spreader.

1 8. The apparatus of claim 7, wherein the buffer layer comprises a
2 catalyst for carbon nanotube growth selected from the group consisting of at
3 least one of Co, Fe and Ni.

1 9. The apparatus of claim 1, wherein the length of at least some of the
2 carbon nanotubes slightly exceeds the width of the gap.

1 10. The apparatus of claim 1, wherein a surface of the heat spreader is
2 formed from a material having a hardness substantially less than that of the
3 nanotubes and free ends of at least some of the carbon nanotubes project from
4 the array of carbon nanotubes to embed them in the surface of the heat spreader.

1 11. The apparatus of claim 10, wherein the surface is a coating.

1 12. The apparatus of claim 1 wherein the length of some of the carbon
2 nanotubes exceeds a predetermined gap by a distance established by the height
3 of a spacer inserted in the gap.

1 13. An apparatus, comprising:
2 an array of carbon nanotubes interposed between a die and a heat spreader, a
3 longitudinal axis of some of the carbon nanotubes substantially commonly
4 oriented and aligned substantially perpendicular to a surface of either at least
5 one of the die or the heat spreader; and
6 a buffer layer formed between the array and a surface of either the die or the
7 heat spreader.

1 14. The apparatus of claim 13, wherein the buffer layer consists of a film
2 selected from the group consisting of Cr, Mo, Ti, W, SiC and TiC.

1 15. The apparatus of claim 13, wherein the length of some of the carbon
2 nanotubes exceeds a predetermined gap by a distance established by the height
3 of a spacer inserted in the gap between the die and the heat spreader.

1 16. A computing system, comprising:
2 a die including a die surface and a circuit electrically coupled to the wireless
3 transceiver;
4 a heat sink; a thermal intermediate interposed between the die surface and
5 the heat sink and having an array of carbon nanotubes and at least one buffer
6 layer coupled to the array of carbon nanotubes and at least one of the heat sink
7 and the die surface; and
8 at least one dynamic random access memory device.

1 17. The system of claim 16, wherein the circuit comprises a processor
2 that acts upon data signals, and may include, for example, a microprocessor.

1 18. The system of claim 16, wherein the buffer layer comprises a metal.

1 19. A method, comprising:
2 coupling a heat source to a first surface of an array of substantially aligned
3 carbon nanotubes;
4 interposing a layer between at least one of either the heat source or a heat
5 sink and at least one of either the first or a second surface of the array of carbon
6 nanotubes; and
7 coupling a surface of the heat sink to the second surface of the array of
8 carbon nanotubes.

1 20. The method of claim 19, wherein coupling a surface of the heat sink
2 to the second surface of the thermal interface material comprises forming a layer

3 on the heat sink and growing the array of substantially aligned carbon nanotubes
4 on the layer.

1 21. The method of claim 19, wherein coupling the heat source to a first
2 surface of an array of substantially aligned carbon nanotubes comprises applying
3 an adhesion promoting layer between the heat source and the array of carbon
4 nanotubes.

1 22. The method of claim 19, also comprising bonding the other surface
2 of the heat source to a substrate.

1 23. A method, comprising:
2 growing an array of substantially aligned carbon nanotubes from a surface of
3 a heat sink; and
4 contacting the surface of a die with free ends of some of the carbon
5 nanotubes of the array of carbon nanotubes.

1 24. The method of claim 23 also comprising forming an adhesion layer
2 on the surface of the die.

1 25. The method of claim 23 also comprising forming an adhesion layer
2 on some of the carbon nanotubes of the array of carbon nanotubes.

1 26. A method, comprising:
2 coupling a heat sink to a first surface of an array of carbon nanotubes;
3 applying an adhesion promoting coating to at least one of either the surface
4 of a heat source or some of the carbon nanotubes of the array of carbon
5 nanotubes; and
6 coupling the heat source to a second surface of the array of carbon
7 nanotubes.

1 27. The method of claim 26, wherein applying an adhesion promoting
2 coating comprises applying a metal.

1 28. The method of claim 26, wherein applying an adhesion promoting
2 coating to some of the carbon nanotubes of the array of carbon nanotubes
3 comprises sputtering a metal coating on the carbon nanotubes.

1 29. The method of claim 26, wherein applying an adhesion layer to the
2 heat sink comprises applying a chemical adhesion promoting layer.